

Determinants of healthy dietary patterns among Iranian adults with type 2 diabetes: evidence from the Stepwise Approach to Noncommunicable Risk Factor Surveillance (STEPS 2021)

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Abstract

purpose

Dietary behavior plays a critical role in the prevention and management of type 2 diabetes mellitus (T2DM). Identifying factors associated with dietary patterns in individuals with T2DM may help improve diabetes management strategies and reduce the risk of long-term complications.

Methods

This cross-sectional study included adults aged ≥ 25 years with T2DM from the nationally representative 2021 Iranian STEPwise Approach to Noncommunicable Disease Risk Factor Surveillance (STEPS) survey. Dietary patterns were derived using principal component analysis of 15 dietary variables and categorized as healthy or unhealthy. Socioeconomic, lifestyle, clinical, and nutrition literacy factors were assessed as potential determinants. Multivariable logistic regression with backward stepwise selection was applied to identify independent predictors of healthy dietary patterns.

Results

Among 2,967 adults with T2DM, 56.7% had a healthy dietary pattern. Healthy dietary patterns were more common among participants with urban residence, higher educational attainment, higher wealth status, health insurance coverage, and greater engagement with nutrition labeling, while smoking was less common in this group (all $p < 0.05$). In multivariable analysis, ≥ 12 years of education (OR = 1.48, 95% CI: 1.20–1.84), middle (OR = 1.23, 95% CI: 1.01–1.49) and highest wealth tertiles (OR = 1.62, 95% CI: 1.31–2.01), and health insurance coverage (OR = 1.51, 95% CI: 1.07–2.12) were independently associated with healthy dietary patterns. Current smoking was inversely associated with healthy dietary adherence (OR = 0.77, 95% CI: 0.60–0.98).

Conclusion

Healthier dietary patterns among Iranian adults with T2DM were associated with socioeconomic status, educational attainment, health insurance coverage, and smoking behavior.

Introduction

Diabetes mellitus is a significant worldwide public health concern of the 21st century, resulting in substantial complications, early death, and economic burdens (1). Iran, located in the high-prevalence Middle East and North Africa (MENA) area, confronts a notably severe and quickly intensifying diabetes epidemic.(2) In 2021, the prevalence of diabetes among Iranian adults was estimated at 14.15%, indicating a 45.5% rise from five years earlier.(3)

Diabetes leads to a wide spectrum of macrovascular and microvascular complications. Macrovascular complications include cardiovascular disease, particularly ischemic heart disease, stroke, and heart failure, which represent the principal causes of death among people with diabetes.(4) Inadequate glycemic control, often attributable to suboptimal dietary practices, is the principal mechanism by which diabetes induces long-term problems.(5) A meta-analysis of 29 randomized controlled trials (n = 1,617) established that low glycemic index dietary patterns decreased HbA1c by an average of - 0.31%, alongside significant reductions in fasting glucose, lipid parameters, body weight, systolic blood pressure, and C-reactive protein, all surpassing concurrent pharmacological or insulin interventions.(6) While higher food quality is often correlated with reduced HbA1c levels in people with diabetes, the data predominantly stems from observational studies, with less evidence from intervention research. The comparability among research is further limited by diverse food quality indexes and possible deficiencies in dietary evaluation methods. Furthermore, the correlation seems to differ among individuals and settings, and the underlying mechanisms remain ambiguous (7).

Current data indicates that healthier eating patterns in individuals with diabetes are often associated with more advantageous social and behavioral variables, such as lower food insecurity, non-smoking status, and improved access to resources.(8) Socioeconomic context appears to play a central role, with food insecurity consistently identified as both a barrier to healthy eating and a factor associated with poorer glycemic control, independent of diet quality.(9) However, there is a lack of comprehensive, diabetes-specific evidence mapping key sociodemographic and clinical predictors, such as education, income, ethnicity, or disease-related factors, highlighting an important gap in understanding the broader determinants of dietary behavior in this population.(10) In this context, the current study aimed to analyze dietary habits and their determinants among Iranian individuals with T2DM, utilizing nationally representative data from the STEPwise approach to NCD risk factor surveillance (STEPS) 2021 survey. We specifically examined the sociodemographic and behavioral aspects associated to healthy dietary patterns.

Methods

Study design and population

This cross-sectional study was conducted using data from the 2021 Iranian STEPS survey, the most recent nationwide survey designed to assess noncommunicable disease (NCD) risk factors among Iranian adults. The STEPS survey was implemented according to the standardized World Health Organization (WHO) STEPS protocol (11). Sampling was performed across all provinces of Iran using a multistage cluster random sampling design to obtain nationally representative estimates of the adult population. Detailed descriptions of the STEPS methodology and sampling have been published previously (12).

Eligible participants were adults aged ≥ 25 years residing in Iran at the time of the survey. For the present study, only adults with T2DM were included. T2DM was defined according to the American Diabetes

Association (ADA) criteria as fasting plasma glucose (FPG) ≥ 126 mg/dL, HbA1c $\geq 6.5\%$, self-reported physician diagnosis of diabetes, or current use of glucose-lowering medications, including oral hypoglycemic agents or insulin (13). Based on interview data and available clinical information, individuals with suspected type 1 diabetes or other specific forms of diabetes (e.g., monogenic diabetes, secondary diabetes, or gestational diabetes) were excluded from the analysis. Participants with missing dietary information or incomplete covariate data were also excluded. Details of participant selection and exclusion criteria are presented in Fig. 1.

The study protocol was approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.EMRI.REC.1404.070), and all procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment in the STEPS 2021 survey.

Socioeconomic, lifestyle, and clinical assessment

Sociodemographic, lifestyle, and clinical variables were obtained from the standardized STEPS 2021 questionnaire and physical examinations. Age, sex, residential, educational, marital and employment status were self-reported. Weight and height were measured based on STEPS protocol which have been published elsewhere (12). Body mass index (BMI) was calculated as weight in kilograms divided by height squared in meters (kg/m^2).

Educational attainment was categorized according to years of schooling as ≤ 6 years, 7–11 years, and ≥ 12 years. Marital status was classified as married or unmarried (single, divorced, separated, or widowed). Employment status was categorized as employed (public/private employee, laborer, freelance, or self-employed) and unemployed (unpaid work, retired, disabled, unemployed seeking or not seeking work). Residential area was categorized as urban or rural.

Wealth index was assessed using household asset information collected in the STEPS survey, including housing characteristics and ownership of household items such as television, LED/LCD TV, refrigerator, washing machine, dishwasher, microwave, laptop, internet access, mobile phone, landline telephone, and car. PCA was applied to generate a wealth index score, and participants were categorized into wealth tertiles representing low, middle, and high status.

Health insurance coverage was categorized as yes (basic insurance, complementary insurance, or both) or no insurance coverage. Smoking status and alcohol consumption within the previous 12 months were self-reported. Current smokers were defined as individuals reporting any daily use of manufactured or hand-rolled cigarettes, cigars, or electronic cigarettes during the past year. Alcohol consumption was defined as self-reported consumption of any amount of any alcoholic beverage during the previous 12 months. Physical activity was assessed using the WHO Global Physical Activity Questionnaire (GPAQ) version 2 and categorized as sufficient (≥ 150 min/week) or insufficient (< 150 min/week).

comorbidity category defined according to the number of coexisting chronic conditions, including hypertension, dyslipidemia, cardiovascular disease (CVD), chronic kidney disease (CKD), and cancer. Participants were categorized as having no comorbidity, one comorbidity, two comorbidities, or three or more comorbidities. Hypertension was defined according to the American Heart Association (AHA)/American College of Cardiology (ACC) guidelines as systolic blood pressure (SBP) ≥ 130 mmHg, diastolic blood pressure (DBP) ≥ 80 mmHg, self-reported physician diagnosis of hypertension, or current use of antihypertensive medication. Dyslipidemia was defined as triglycerides (TG) ≥ 150 mg/dL, total cholesterol (TC) ≥ 200 mg/dL, LDL cholesterol (LDL-C) ≥ 70 mg/dL, low HDL cholesterol (HDL-C) (< 40 mg/dL in males or < 50 mg/dL in females), or current use of lipid-lowering medications (14). CVD was defined as a self-reported history of coronary heart disease, myocardial infarction, angina pectoris, stroke, coronary artery bypass graft surgery, or percutaneous coronary intervention (angioplasty). CKD was defined as an estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m², calculated using the CKD-EPI equation, and/or self-reported physician diagnosis of chronic kidney disease. Cancer was defined as a self-reported physician diagnosis of any malignant neoplasm at the time of the survey.

Dietary pattern assessment and nutrition score

Dietary intake data were collected using the nutrition module of the 2021 STEPS questionnaire, which included information on meal frequency, breakfast consumption, fruit and vegetable intake, dairy products, red and processed meat, fish, whole grains, sugar-sweetened beverages, nuts, and salt-related dietary behaviors.

Prior to analysis, dietary variables were converted into standardized scores ranging from 0 to 1 based on predefined scoring algorithms developed in consultation with nutrition experts. Higher scores reflected healthier dietary behaviors. Fruit and vegetable intake was estimated based on reported weekly frequency and portion size, and converted into average daily intake. Frequency-based food items were scored according to the healthfulness of consumption patterns, with higher scores assigned to healthier intake frequencies.

PCA was then applied to 15 standardized dietary variables to derive an overall dietary pattern score. The suitability of PCA was confirmed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (KMO > 0.6) and Bartlett’s test of sphericity ($p < 0.05$). The first principal component, which explained the largest proportion of variance in dietary responses, was retained as the composite nutrition score. This score ranged from 0 to 1, with higher values indicating healthier dietary patterns. Based on this score, participants were categorized into two groups: healthy diet (nutrition score ≥ 0.5) and unhealthy diet (nutrition score < 0.5).

Nutrition literacy and food labeling behaviors assessment

Nutrition literacy and food labeling behaviors were assessed using self-reported questionnaire items from the STEPS survey which is provided in the **Supplementary File**. Familiarity with the traffic light guide was defined as participants reporting awareness or recognition of the front-of-package traffic light food labeling system used on packaged food products in Iran. Attention to the traffic light guide was defined as self-reported use or consideration of traffic light labels during food purchasing or selection. Attention to nutrition facts was defined as self-reported reading or paying attention to nutrition facts panels on packaged food products during food selection or purchase. All variables were categorized dichotomously as Yes or No.

Statistical analysis

All analyses accounted for the complex survey design of the STEPS study, including sampling weights, clustering, and stratification (12). Descriptive statistics were calculated for all variables. Continuous variables were presented as means with 95% confidence intervals (CIs), while categorical variables were reported as percentages with corresponding 95% CIs. Normality of data distribution was assessed using the Kolmogorov–Smirnov test and Q–Q plots. Comparisons between diet groups were performed using survey-weighted chi-square tests for categorical variables and adjusted Wald tests for continuous variables. Univariable logistic regression analyses were conducted to assess associations between covariates and dietary status. Variables with $p < 0.20$ in univariable analyses were entered into the multivariable model, and backward stepwise selection was applied to identify independent determinants of healthy dietary adherence. All analyses were performed using Stata version 18 (StataCorp LLC, TX, USA) and R version 4.3.2. A two-tailed p -value < 0.05 was considered statistically significant.

Results

Baseline characteristics

A total of 27,874 participants were enrolled in the STEPS 2021 survey. Among them, 3,822 adults aged ≥ 25 years with T2DM were identified. After excluding individuals with missing dietary or covariate data, 2,967 participants (1,717 females) were included in the final analysis. Table 1 summarizes the sociodemographic, lifestyle, clinical, and nutrition literacy characteristics of adults with T2DM according to dietary status. Several socioeconomic characteristics differed significantly according to dietary status.

Table 1

Sociodemographic, lifestyle, clinical, and nutrition literacy characteristics of adults with T2DM according to dietary status

Characteristic	Total N = 2967	Unhealthy diet N = 1286	Healthy diet N = 1681	p-value
Demographic and Anthropometric Characteristics				
Age (years)	58.34 [57.86, 58.82]	58.23 [57.59, 58.87]	58.41 [57.24, 59.07]	0.757
BMI (kg/m²)	29.38 [29.17, 29.59]	29.20 [28.92, 29.48]	29.49 [29.20, 29.78]	0.225
Sex				
Female	57.94 [55.94, 59.90]	57.76 [55.13, 60.34]	58.05 [55.24, 60.81]	0.88
Male	42.06 [40.10, 44.06]	42.24 [39.66, 44.87]	41.95 [39.19, 44.76]	
Socioeconomic characteristics				
Area				
Rural	25.76 [24.06, 27.54]	29.66 [27.31, 32.13]	23.29 [21.00, 25.76]	< 0.001
Urban	74.24 [72.46, 75.94]	70.34 [67.87, 72.69]	76.71 [74.24, 79.00]	
Education				
≤ 6 years	60.62 [58.63, 62.58]	67.07 [64.52, 69.53]	56.53 [53.72, 59.31]	< 0.001
7–11 years	14.55 [13.17, 16.04]	14.36 [12.56, 16.38]	14.67 [12.77, 16.78]	
≥12 years	24.83 [23.11, 26.64]	18.57 [16.60, 20.71]	28.80 [26.32, 31.42]	
Marital status				
Unmarried	17.83 [16.35, 19.42]	19.12 [17.09, 21.32]	17.02 [15.00, 19.25]	0.172
Married	82.17 [80.58, 83.65]	80.88 [78.68, 82.91]	82.98 [80.75, 85.00]	
Employment status				
Unemployed	75.47 [73.70, 77.16]	76.41 [74.10, 78.58]	74.88 [72.35, 77.24]	0.364

Characteristic	Total N = 2967	Unhealthy diet N = 1286	Healthy diet N = 1681	p-value
Demographic and Anthropometric Characteristics				
Employed	24.53 [22.84, 26.30]	23.59 [21.42, 25.90]	25.12 [22.76, 27.65]	< 0.001
Wealth Tertile				
Tertile 1 (Lowest)	32.69 [30.84, 34.60]	39.25 [36.69, 41.88]	28.53 [26.04, 31.17]	
Tertile 2 (Middle)	34.20 [32.32, 36.13]	34.99 [32.51, 37.55]	33.70 [31.08, 36.41]	
Tertile 3 (Highest)	33.11 [31.24, 35.04]	25.76 [23.57, 28.08]	37.77 [35.08, 40.53]	
Health Insurance				
No	5.65 [4.80, 6.63]	7.18 [5.89, 8.72]	4.68 [3.63, 6.03]	0.008
Yes	94.35 [93.37, 95.20]	92.83 [91.28, 94.11]	95.32 [93.97, 96.37]	
Lifestyle-related behaviors				
Physical activity				
Low Activity	60.12 [58.14, 62.06]	60.37 [57.78, 62.91]	59.96 [57.17, 62.69]	0.829
High Activity	39.88 [37.94, 41.86]	39.63 [37.09, 42.22]	40.04 [37.31, 42.83]	
Smoking Status				
Non-smoker	87.55 [86.15, 88.82]	85.73 [83.66, 87.57]	88.70 [86.78, 90.38]	0.028
Current Smoker	12.45 [11.18, 13.85]	14.27 [12.43, 16.34]	11.30 [9.62, 13.22]	
Alcohol consumption				
No	97.96 [97.30, 98.47]	97.98 [96.98, 98.65]	97.96 [97.00, 98.61]	0.974
Yes	2.04 [1.53, 2.70]	2.02 [1.35, 3.03]	2.04 [1.39, 3.00]	
Clinical and metabolic characteristics				
Comorbidity Category				

Characteristic	Total N = 2967	Unhealthy diet N = 1286	Healthy diet N = 1681	p-value
Demographic and Anthropometric Characteristics				
No Disease	0.48 [0.26, 0.89]	0.69 [0.31, 1.53]	0.35 [0.13, 0.92]	0.297
One Disease	13.87 [12.53, 15.33]	12.54 [10.87, 14.42]	14.71 [12.84, 16.81]	
Two Diseases	46.35 [44.36, 48.36]	46.62 [44.00, 49.26]	46.18 [43.39, 49.01]	
Three or More Diseases	39.30 [37.35, 41.28]	40.15 [37.59, 42.77]	38.76 [36.04, 41.54]	
Hypertension				
No	18.18 [16.68, 19.79]	18.64 [16.62, 20.83]	17.89 [15.84, 20.15]	0.629
Yes	81.82 [80.21, 83.32]	81.36 [79.17, 83.38]	82.11 [79.85, 84.16]	
Dyslipidemia				
No	2.68 [2.09, 3.45]	1.78 [1.15, 2.76]	3.26 [2.40, 4.40]	0.024
Yes	97.32 [96.55, 97.92]	98.22 [97.24, 98.85]	96.75[95.60, 97.60]	
Nutrition literacy and food labeling behaviors				
Familiar with traffic light guide				
No	69.16 [67.27, 71.00]	71.12 [68.66,73.47]	67.92 [65.23,70.5]]	0.078
Yes	30.84 [29.00, 32.73]	28.88 [26.53,31.34]	32.08 [29.5,34.77]	
Attention to traffic light guide				
No	72.99 [71.16, 74.75]	75.16 [72.81,77.37]	71.61 [69,74.09]	< 0.001
Yes	27.01 [25.25, 28.84]	24.84 [22.63,27.19]	28.39 [25.91,31]	
Attention to nutrition facts				
No	57.30 [55.29, 59.27]	60.67 [58.06,63.21]	55.16 [52.34,57.95]]	< 0.001

Characteristic	Total N = 2967	Unhealthy diet N = 1286	Healthy diet N = 1681	p-value
Demographic and Anthropometric Characteristics				
Yes	42.70 [40.73, 44.71]	39.33 [36.79, 41.94]	44.84 [42.05, 47.66]	
- Nutrition score was derived from principal component analysis (PCA) of 15 dietary variables and range from 0 to 1, with higher scores indicating healthier dietary patterns. Diet status was categorized to: Healthy diet was defined as a PCA-derived nutrition score ≥ 0.5; Unhealthy diet was defined as PCA-derived nutrition score < 0.5. - Education: Categorized based on years of schooling (≤ 6 years, 7–11 years, ≥ 12 years). - Marital status: Unmarried (single, divorced, separated, widowed); Married. - Employment status: Unemployed (unpaid work, retired, disabled, unemployed seeking or not seeking work); Employed (public/private sector employee, labor, freelance, self-employed). - Physical activity: Low activity (< 150 min/week), High activity (≥ 150 min/week). - Wealth tertiles: Derived from PCA of household assets (Tertile 1 = lowest, Tertile 3 = highest). - Smoking status: Current smoker (self-reported smoking within the past year). - Alcohol consumption: Self-reported consumption within past year. - Comorbidity category: Number of comorbidities among hypertension, dyslipidemia, cardiovascular disease, cancer, and chronic kidney disease. - Hypertension: SBP ≥ 130 mmHg OR DBP ≥ 80 mmHg OR antihypertensive medication. - Dyslipidemia: Defined as high triglycerides (≥ 150 mg/dL) or high cholesterol (≥ 200 mg/dL) or high LDL (≥ 70 mg/dL) or low HDL (< 40 mg/dL in men, < 50 mg/dL in women) or use of lipid-lowering medication. Abbreviations: BMI, body mass index; OR, odds ratio; CI, confidence interval; PCA, principal component analysis; SBP, systolic blood pressure; DBP, diastolic blood pressure.				

Among 2,967 adults with T2DM, 1,681 (56.7%) were classified as having a healthy dietary pattern and 1,286 (43.3%) as having an unhealthy dietary pattern based on the PCA-derived nutrition score. Mean age and BMI did not differ significantly between the two groups ($p > 0.05$).

Significant differences were observed across several socioeconomic characteristics. Participants with a healthy dietary pattern were more likely to reside in urban areas compared with those with an unhealthy dietary pattern (76.71%, 95% CI: 74.24–79.00 vs. 70.34%, 95% CI: 67.87–72.69; $p < 0.001$), whereas rural residence was more common among individuals with an unhealthy diet (29.66%, 95% CI: 27.31–32.13 vs. 23.29%, 95% CI: 21.00–25.76). Educational attainment also differed significantly between groups ($p < 0.001$). Participants with a healthy dietary pattern more frequently had ≥ 12 years of education (28.80%, 95% CI: 26.32–31.42) compared with those with an unhealthy dietary pattern (18.57%, 95% CI: 16.60–20.71), while low educational attainment (≤ 6 years) was more prevalent among those with an unhealthy

diet (67.07%, 95% CI: 64.52–69.53 vs. 56.53%, 95% CI: 53.72–59.31). Similarly, individuals with a healthy dietary pattern were more likely to belong to the highest wealth tertile (37.77%, 95% CI: 35.08–40.53) than those with an unhealthy dietary pattern (25.76%, 95% CI: 23.57–28.08), whereas membership in the lowest wealth tertile was more common among participants with an unhealthy diet (39.25%, 95% CI: 36.69–41.88 vs. 28.53%, 95% CI: 26.04–31.17) ($p < 0.001$). Health insurance coverage was also slightly higher among participants with a healthy dietary pattern (95.32%, 95% CI: 93.97–96.37) than among those with an unhealthy dietary pattern (92.83%, 95% CI: 91.28–94.11; $p = 0.008$).

Regarding lifestyle behaviors, smoking was significantly less common among participants with a healthy dietary pattern than among those with an unhealthy dietary pattern (11.30%, 95% CI: 9.62–13.22 vs. 14.27%, 95% CI: 12.43–16.34; $p = 0.028$). No significant differences were observed for physical activity level or alcohol consumption.

Among clinical characteristics, the prevalence of dyslipidemia was slightly lower among participants with a healthy dietary pattern compared with those with an unhealthy dietary pattern (96.75%, 95% CI: 95.60–97.60 vs. 98.22%, 95% CI: 97.24–98.85; $p = 0.024$). However, no significant differences were observed in hypertension status or comorbidity burden between dietary groups.

Differences were also observed in nutrition literacy and food-labeling behaviors. Participants with a healthy dietary pattern were more likely to report paying attention to traffic light nutrition labels (28.39%, 95% CI: 25.91–31.00) compared with those with an unhealthy dietary pattern (24.84%, 95% CI: 22.63–27.19; $p < 0.001$). Likewise, attention to nutrition facts labels was more common among individuals with a healthy dietary pattern (44.84%, 95% CI: 42.05–47.66) than among those with an unhealthy dietary pattern (39.33%, 95% CI: 36.79–41.94; $p < 0.001$). Familiarity with the traffic light guide tended to be higher among participants with a healthy dietary pattern (32.08%, 95% CI: 29.50–34.77) than among those with an unhealthy dietary pattern (28.88%, 95% CI: 26.53–31.34), although this difference did not reach statistical significance ($p = 0.078$). The distribution of nutrition literacy indicators across healthy and unhealthy dietary pattern groups is presented in Fig. 2.

Univariate logistic regression analysis

Table 2 presents the results of the univariate logistic regression analyses examining factors associated with a healthy dietary pattern among adults with T2DM.

Table 2

Univariate logistic regression analysis of factors associated with dietary pattern among T2DM patients

Variable	Category	Odds Ratio (OR)	95% Confidence Interval	p-value
Sex	Female	Reference	Reference	Reference
	Male	.987	[0.844, 1.155]	0.880
Age (continuous)		1.001	[.994, 1.007]	0.691
BMI (continuous)		1.010	[.995, 1.026]	0.162
Area	Rural	Reference	Reference	Reference
	Urban	1.388	[1.163, 1.656]	< 0.001
Education	≤ 6 years	Reference	Reference	Reference
	7–12	1.211	[0.960, 1.544]	0.105
	≥ 12 years	1.840	[1.522, 2.223]	< 0.001
Marital Status	Unmarried	Reference	Reference	Reference
	Married	1.151	[.940, 1.411]	0.172
Employment Status	Unemployed	Reference	Reference	Reference
	Employed	1.086	[.907, 1.301]	0.364
Physical Activity	Low Activity	Reference	Reference	Reference
	High Activity	1.017	[.869, 1.190]	0.829
Wealth Tertile	Tertile 1 (Lowest)	Reference	Reference	Reference
	Tertile 2 (Middle)	1.324	[1.095, 1.602]	0.004
	Tertile 3 (Highest)	2.017	[1.663, 2.446]	< 0.001
Smoking Status	Non-smoker	Reference	Reference	Reference
	Current Smoker	.765	[.601, .972]	0.029
Alcohol Consumption	No	Reference	Reference	Reference
	Yes	1.009	[.570, 1.785]	0.974
Health Insurance	No	Reference	Reference	Reference
	Yes	1.573	[1.119, 2.211]	0.009
Familiar with Traffic Light Guide	No	Reference	Reference	Reference
	Yes	1.163	[.983, 1.376]	0.078

Variable	Category	Odds Ratio (OR)	95% Confidence Interval	p-value
Attention to Traffic Light Guide	No	Reference	Reference	Reference
	Yes	1.199	[1.006, 1.428]	0.042
Attention to Nutrition Facts	No	Reference	Reference	Reference
	Yes	1.253	[1.072, 1.466]	0.005
Comorbidity Category	No Disease	Reference	Reference	Reference
	One Disease	2.328	[0.640, 4.359]	0.200
	Two Diseases	1.965	[0.546, 3.987]	0.300
	Three or More Diseases	1.914	[0.532, 3.462]	0.320
Hypertension	No	Reference	Reference	Reference
	Yes	1.050	[0.858, 1.286]	0.629
Dyslipidemia	No	Reference	Reference	Reference
	Yes	0.539	[0.312, .930]	0.027

-Outcome variable: diet status (healthy vs. unhealthy). Healthy diet was defined as PCA-derived nutrition score ≥ 0.5 ; unhealthy diet was defined as PCA-derived nutrition score < 0.5 .

- Education: Categorized based on years of schooling (≤ 6 years, 7–11 years, ≥ 12 years).

- Marital status: Unmarried (single, divorced, separated, widowed); Married.

- Physical activity: Low activity (< 150 min/week), High activity (≥ 150 min/week).

- Wealth tertiles: Derived from PCA of household assets (Tertile 1 = lowest, Tertile 3 = highest).

- Smoking status: Current smoker (self-reported smoking within the past year).

- Alcohol consumption: Self-reported consumption within past year.

- Comorbidity category: Number of comorbidities among hypertension, dyslipidemia, cardiovascular disease, cancer, and chronic kidney disease.

- Attention to Nutrition Facts: Recoded as yes (always, often, sometimes, rarely) vs. no (never).

- Hypertension: SBP ≥ 130 mmHg OR DBP ≥ 80 mmHg OR antihypertensive medication.

- Dyslipidemia: Defined as high triglycerides (≥ 150 mg/dL) or high cholesterol (≥ 200 mg/dL) or high LDL (≥ 70 mg/dL) or low HDL (< 40 mg/dL in men, < 50 mg/dL in women) or use of lipid-lowering medication.

Abbreviations: OR, odds ratio; CI, confidence interval; PCA, principal component analysis.

Among sociodemographic characteristics, urban residence was significantly associated with greater odds of having a healthy dietary pattern compared with rural residence (OR = 1.39, 95% CI: 1.16–1.66; $p < 0.001$). Educational attainment demonstrated a positive gradient with dietary quality. Compared with participants with ≤ 6 years of education, those with ≥ 12 years of education had 84% higher odds of adhering to a healthy dietary pattern (OR = 1.84, 95% CI: 1.52–2.22; $p < 0.001$), whereas the association for individuals with 7–11 years of education was not statistically significant (OR = 1.21, 95% CI: 0.96–1.54; $p = 0.105$). Similarly, wealth status was strongly associated with dietary pattern. Compared with participants in the lowest wealth tertile, those in the middle and highest tertiles had significantly higher odds of a healthy dietary pattern (OR = 1.32, 95% CI: 1.10–1.60; $p = 0.004$ and OR = 2.02, 95% CI: 1.66–2.45; $p < 0.001$, respectively). Participants with health insurance also had higher odds of reporting a healthy dietary pattern than uninsured individuals (OR = 1.57, 95% CI: 1.12–2.21; $p = 0.009$).

Regarding lifestyle factors, current smokers had significantly lower odds of having a healthy dietary pattern compared with non-smokers (OR = 0.77, 95% CI: 0.60–0.97; $p = 0.029$), corresponding to approximately 23% lower odds of adherence to a healthy dietary pattern.

Among clinical variables, dyslipidemia was inversely associated with healthy dietary patterns. Participants with dyslipidemia had 46% lower odds of adhering to a healthy dietary pattern compared with those without dyslipidemia (OR = 0.54, 95% CI: 0.31–0.93; $p = 0.027$). In contrast, neither hypertension nor comorbidity burden was significantly associated with dietary pattern (all $p > 0.05$).

Nutrition literacy and food-labeling behaviors were also associated with dietary choices. Participants who reported paying attention to traffic light nutrition labels had 20% higher odds of having a healthy dietary pattern compared with those who did not (OR = 1.20, 95% CI: 1.01–1.43; $p = 0.042$). Likewise, attention to nutrition facts labels was associated with 25% higher odds of a healthy dietary pattern (OR = 1.25, 95% CI: 1.07–1.47; $p = 0.005$). Familiarity with the traffic light guide showed a positive but non-significant association with healthy dietary behavior (OR = 1.16, 95% CI: 0.98–1.38; $p = 0.078$).

Multivariable logistic regression analysis

Table 3 presents the multivariable logistic regression analysis of factors independently associated with adherence to a healthy diet among adults with T2DM. Higher educational attainment remained significantly associated with healthier dietary patterns. Participants with ≥ 12 years of education had 48% higher odds of adhering to a healthy diet compared with those with ≤ 6 years of education (OR = 1.484, 95% CI: 1.198, 1.839, $p < 0.001$).

Table 3

Multivariable logistic regression analysis of factors associated with healthy Diet among patients with T2DM

Variable	Category	OR	95% CI	p-value
Area	Rural	Reference	Reference	Reference
	Urban	1.171	[0.971, 1.412]	0.098
Education	≤ 6 years	Reference	Reference	Reference
	7–11 years	1.076	[0.849, 1.363]	0.542
	≥ 12 years	1.484	[1.198, 1.839]	< 0.001
Wealth Tertile	Tertile 1 (Lowest)	Reference	Reference	Reference
	Tertile 2 (Middle)	1.225	[1.010, 1.487]	0.039
	Tertile 3 (Highest)	1.623	[1.313, 2.007]	< 0.001
Smoking Status	Non-smoker	Reference	Reference	Reference
	Current Smoker	0.766	[0.597, 0.983]	0.03
Health Insurance	No	Reference	Reference	Reference
	Yes	1.505	[1.069, 2.119]	0.019
Attention to Traffic Light Guide	No	Reference	Reference	Reference
	Yes	0.904	[0.712, 1.146]	0.406
Attention to Nutrition Facts	No	Reference	Reference	Reference
	Yes	1.118	[0.903, 1.383]	0.304
Dyslipidemia	No	Reference	Reference	Reference
	Yes	0.598	[0.342, 1.048]	0.073

-Outcome variable: diet status (healthy vs. unhealthy). Healthy diet was defined as PCA-derived nutrition score ≥ 0.5 ; unhealthy diet was defined as PCA-derived nutrition score < 0.5 . Variables with $p < 0.20$ in univariate analysis were entered into the multivariate model using backward stepwise selection.

- Education: Categorized based on years of schooling (≤ 6 years, 7–11 years, ≥ 12 years).

- Wealth tertiles: Derived from PCA of household assets (Tertile 1 = lowest, Tertile 3 = highest).

- Smoking status: Current smoker (self-reported smoking within the past year).

- Attention to Nutrition Facts: Recoded as yes (always, often, sometimes, rarely) vs. no (never).

- Dyslipidemia: Defined as high triglycerides (≥ 150 mg/dL) or high cholesterol (≥ 200 mg/dL) or high LDL (≥ 70 mg/dL) or low HDL (< 40 mg/dL in men, < 50 mg/dL in women) or use of lipid-lowering

Variable	Category	OR	95% CI	p-value
medication.				
Abbreviations: OR, odds ratio; CI, confidence interval; PCA, principal component analysis.				

A significant socioeconomic gradient was also observed. Compared with participants in the lowest wealth tertile, those in the middle and highest wealth tertiles had 23% (OR = 1.225, 95% CI: 1.010, 1.487, $p = 0.039$) and 62% (OR = 1.623, 95% CI: 1.313, 2.007, $p < 0.001$) higher odds of following a healthy diet, respectively. In addition, participants with health insurance had significantly higher odds of adhering to a healthy diet than uninsured individuals (OR = 1.505, 95% CI: 1.069, 2.119, $p = 0.019$).

Current smoking was inversely associated with healthy dietary adherence, with smokers showing significantly lower odds of having a healthy diet compared with non-smokers (OR = 0.766, 95% CI: 0.597, 0.983, $p = 0.03$).

Discussion

Dietary patterns and food choices play a central role in the prevention and management of T2DM. Identifying the determinants of dietary behavior among individuals with diabetes is essential for improving both clinical care and public health strategies (15). In this nationally representative sample of Iranian adults with T2DM, a relatively high proportion of participants (43.3%) exhibited an unhealthy dietary pattern. We observed that adherence to a healthy dietary pattern was strongly patterned by socioeconomic status. Specifically, higher educational attainment, greater household wealth, and having health insurance were independently associated with healthier dietary choices, while current smoking remained a consistent negative correlate of healthy diet adherence. In contrast, most clinical variables including BMI, hypertension, and comorbidity burden, showed no significant relationship with dietary status after adjustment, which indicate that dietary behavior in this population is not primarily driven by disease severity or clinical complexity.

This study demonstrates a pronounced socioeconomic gradient in dietary behavior among individuals with T2DM. Participants in the highest wealth tertile had substantially higher odds of following a healthy diet compared with those in the lowest tertile. Consistent with our findings, evidence from a recent scoping review of observational studies in high-income countries has reported that lower education, income, and socioeconomic status are consistently associated with poorer dietary quality (16). Individuals with lower socioeconomic status may face several barriers to healthy eating and effective diabetes self-management, including limited financial resources, reduced access to healthy foods, transportation difficulties, and lower access to preventive healthcare services (17). The nationwide Iran DiaCare study also demonstrated that optimal diabetes control and achievement of therapeutic targets were more common among socioeconomically advantaged individuals (18).

The relationship between dietary pattern and food cost remains complex and, to some extent, controversial (19). While several studies have suggested that healthier dietary patterns are associated

with higher food expenditures, Others have reported that healthy diets may be achievable at costs comparable to or even lower than unhealthy dietary patterns, particularly when processed foods are reduced and expensive animal-based products such as red and processed meats are partially replaced with more affordable plant-based protein sources. (20, 21). These inconsistencies likely reflect the personalized and context-dependent nature of dietary behavior, underscoring its embedding within a complex social and environmental context. Factors such as urban or rural residence, local food availability, socioeconomic status, age, physical capacity, and access to transportation may all influence an individual's ability to obtain and adhere to healthy dietary recommendations (22). Support this, a national STEPS survey from Kenya as a low- and middle-income country, reported that unhealthy dietary behaviors, including high salt and sugar intake and low fruit and vegetable consumption, were significantly associated with several sociodemographic factors such as male sex, younger age, urban residence, and educational status (23). In addition to socioeconomic determinants, smoking was independently and inversely associated with adherence to a healthy dietary pattern. This finding supports the concept of lifestyle clustering, whereby smoking co-occurs with other unhealthy behaviors, including lower diet quality and reduced adherence to dietary recommendations. This pattern has been consistently reported in population-based studies, suggesting that smoking may reflect broader behavioral and psychosocial risk profiles rather than an isolated exposure (24, 25).

Health insurance coverage was independently associated with healthier dietary patterns in our study. Health insurance may facilitate more frequent contact with healthcare providers, greater exposure to diabetes education, and improved access to preventive and counseling services, which in turn can support healthier dietary behaviors and better self-management among individuals with T2DM (26). Evidence from national STEPS surveys in Iran (2004–2016) has primarily demonstrated an association between health insurance and improved diabetes detection, treatment, and glycemic control (27). In line with this, a recent systematic review has also reported that health insurance coverage is generally associated with healthier lifestyle behaviors, including better dietary habits, increased physical activity, and lower prevalence of some non-communicable diseases (28).

Educational attainment emerged as an independent determinant of healthy dietary behavior in the present study. Those with > 12 years of schooling had 48% higher odds of adhering to a healthy dietary pattern. Participants with healthier diets also more frequently reported engagement with food labeling systems and nutrition-related information. Previous evidence has also suggested that health literacy may partially mediate the relationship between education and health behaviors, including dietary quality (29). Additionally, low health literacy is associated with unhealthy dietary behaviors, insufficient fruit and vegetable intake, obesity, lower physical activity, and poorer social engagement among older adults (30). Notably, significant associations were observed for attention to food labels but not for simple familiarity with the traffic light labeling system. This finding suggests that awareness of nutrition information alone may be insufficient to influence dietary behavior unless individuals actively use such information when making food choices. Individuals with lower educational attainment or limited health literacy may face greater challenges in interpreting nutrition information and translating dietary recommendations into appropriate food choices, even when healthier options are available or affordable (31).

Our findings are consistent with evidence from Iran indicating that the effectiveness of traffic light and nutrition labeling systems depends not only on their availability but also on consumers' ability to understand and utilize the information provided. A qualitative study conducted among Iranian consumers and stakeholders reported that traffic light labels were generally perceived as easier to understand than conventional nutrition facts panels; however, limited nutrition knowledge, difficulties in label interpretation, and inadequate consumer education were identified as major barriers to effective label use (32). The same study emphasized that education and public awareness initiatives could enhance the impact of nutrition labeling on food purchasing behaviors (33). Collectively, these findings suggest that interventions aimed at improving dietary quality should extend beyond increasing awareness of nutrition labeling systems and focus on strengthening nutrition literacy and consumers' ability to apply label information in real-world food environments (34). Therefore, the affordability and accessibility of healthy diets should be considered within a broader framework that encompasses educational, social, and environmental factors influencing dietary choices (35).

This study has several strengths, including the use of a large nationally representative sample of Iranian adults with T2DM. Inclusion of nutrition literacy and food labeling behaviors provided further insight into behavioral correlates of dietary patterns. However, the cross-sectional design limits causal inference. Dietary intake and nutrition literacy indicators were self-reported, which may introduce recall bias. Moreover, nutrition literacy was assessed using proxy measures rather than validated instruments. Prospective and intervention-based studies may help clarify whether improving health literacy, nutrition education, and access to affordable healthy foods can reduce socioeconomic disparities in dietary quality and diabetes outcomes.

In conclusion, healthier dietary patterns among Iranian adults with T2DM were associated with higher educational attainment, greater household wealth, and health insurance coverage, while smoking was inversely associated with healthy dietary adherence. Together, these findings highlight the potential contribution of socioeconomic and behavioral factors to dietary choices among adults with diabetes and underscore the importance of addressing social inequalities when designing nutrition-related interventions and diabetes management strategies.

Declarations

Competing Interests:

The authors declare that they have no competing interests.

Additional information

AI Use Disclosure

Artificial intelligence tools were used solely to improve the clarity, grammar, and language of the manuscript. These tools were not used to generate scientific content, interpret data, draw conclusions, or write the manuscript. All scientific content, analyses, and interpretations were developed by the authors based exclusively on the original data and cited references. The authors take full responsibility for the accuracy, integrity, and originality of the work.

Comparison of nutrition label familiarity and attention between participants with healthy and unhealthy dietary patterns among adults with T2DM.

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Author Contribution

F.S.M., A.A.B., F.F., and Y.A. contributed to the study design. F.S.M., A.A.B., and F.F. wrote the main manuscript text. N.C. performed data curation and statistical analysis. S.S., A.M., H.A., N.P., and E.N.-E. critically revised the manuscript. Y.A. and S.A. supervised the study. B.L. provided overall supervision and served as the corresponding author. All authors reviewed and approved the final manuscript.

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Data availability statement:

The data underlying this study is not publicly available due to sensitive patient information and ethical restrictions imposed by Endocrinology and Metabolism Research Institute (EMRI).

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Figures

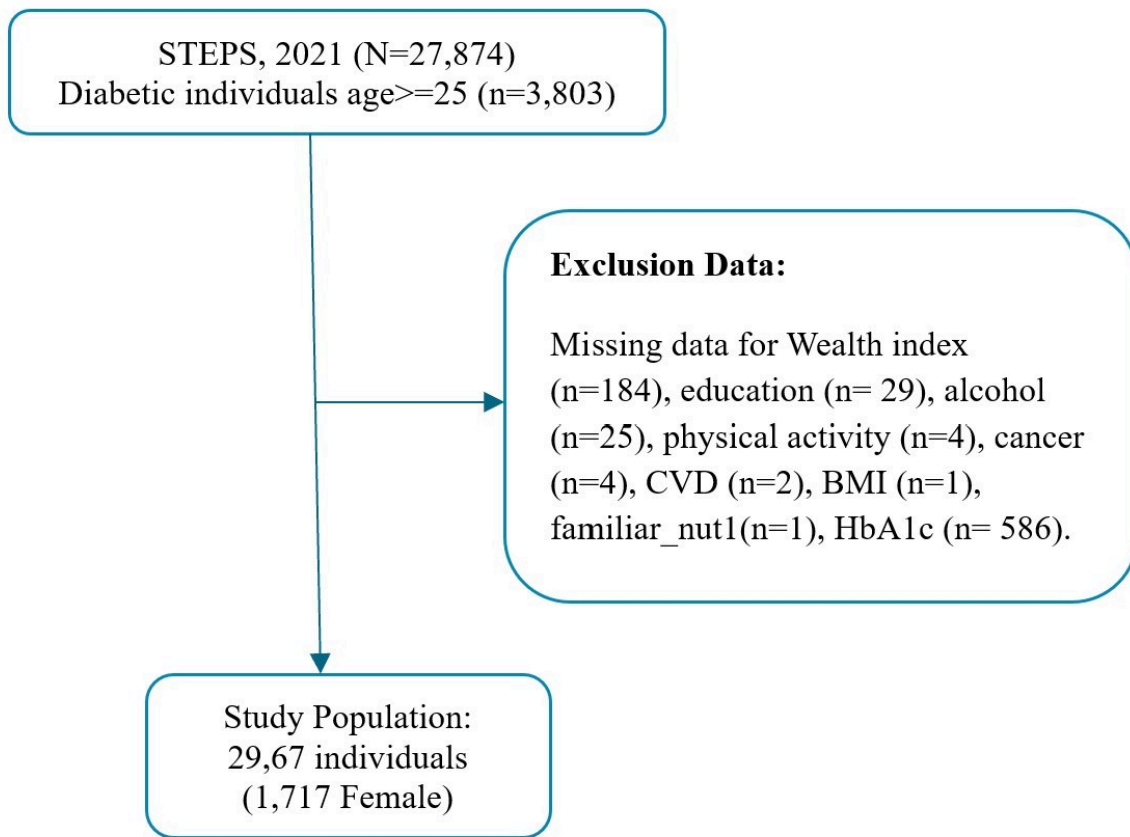


Figure 1

Study Flowchart

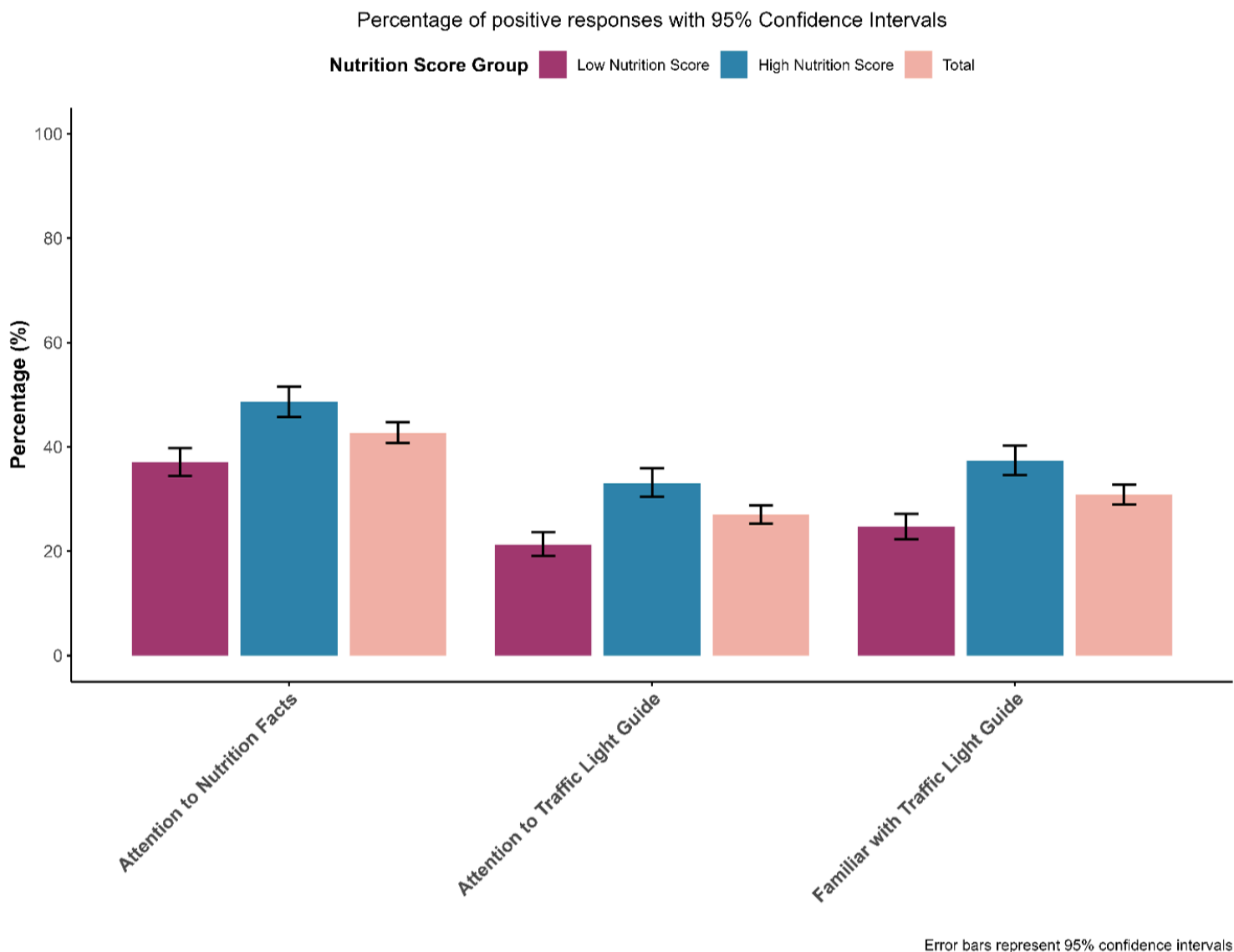


Figure 2

Comparison of nutrition literacy indicators (familiarity with traffic light guide, attention to traffic light labels, and attention to nutrition facts labels) between participants with healthy and unhealthy dietary patterns among Iranian adults with type 2 diabetes. Data are presented as weighted percentages with 95% confidence intervals. All $p < 0.05$

Supplementary Files

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